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A Review of Economic Incentives to Promote Decarbonization Alternatives in Maritime and Inland Waterway Transport Modes

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Abstract: Public policies and economic incentives are widely used as a strategy to stimulate the use of green technologies and low-emission practices in the waterborne transport sector. Since the Paris Agreement, countries have been encouraged to implement more strategies to reduce greenhouse gas emissions and to build resilience against climate change impacts in developing countries. This article presents a literature review on policies, regulations, and programs that represent economic incentives to promote alternatives to decarbonize maritime and inland waterway transport in sixteen countries, including Colombia. More than one hundred thirty sources of information were reviewed, including official portals of governments, port authorities and organizations, and scientific articles; therefore, the incentives found were grouped into three categories: project financing, differentiated port tariffs, and incentives to cover onshore power service fees. As a result of this review, it was found that differentiated port tariffs were the most common type of incentive. Finally, the specific case of Colombia was analyzed, which provides a deeper perspective of current policies and measures aimed at encouraging the decarbonization of waterborne transport and compares them with the international panorama.

Keywords: alternative fuels; economic incentives; maritime transport; inland waterway transport; greenhouse gases; economic instruments; emission reductions; green incentives

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1. Introduction

The transport sector contributes to greenhouse gas emissions (GHG [1,2]). Within this sector, shipping contributes around 3% of global GHG emissions, and these emissions continue to increase despite improvements in the efficiency of port operations and ships [3]. In addition, inland waterway transport also makes a significant contribution to emissions, but its effects are more evident at a local level [4,5]. Studies and research on emissions and decarbonization strategies in inland waterway mode are limited, as these have been largely prioritized to maritime transport due to their higher contribution to emissions compared to inland waterway mode [5,6]. The effects and urgent threat of climate change require a joint effort to reduce emissions from both modes of transport. In this regard, the International Energy Agency states that emissions from the transport sector must be reduced by 20% by 2030 if the objectives of the net zero emission by 2050 scenario are to be achieved [7].

Achieving this optimistic scenario will depend on the implementation of policies and measures to incentivize the use of less carbon-intensive technologies and alternative fuels [8–10]. In this sense, transport electrification, the harnessing of renewable energies, and the improvement of energy efficiency have proven to be fundamental pillars for contributing to the decarbonization of the transport sector [10–12]. However, the maritime and inland waterway modes face many technological and economic challenges, as the efficiency and capacity of zero-emission technologies are not sufficient for long-distance

transport and other options such as onshore power supply, low-carbon port infrastructure, and fleet modernization require large investments [13,14]. In spite of that, research has affirmed that these challenges can be addressed through the implementation of public policies and economic incentives that encourage social actors involved in maritime and inland waterway transport (government, institutions, port authorities, and companies) to act and change their behavior [15,16]. Therefore, the transition from mobility to low-carbon mobility is enabled.

In this context, economic incentives are defined as financial incentives given to certain actors to carry out an action or to behave in a certain way [17]. Within this framework, subsidies, discounts, tax exemptions, and project financing programs are forms of financial support from the government and some private and public institutions to reward environmentally friendly actions. Typical actions include the technological replacement of ships and boats with electric mobility, the implementation of alternative fuels, and research for the development of more efficient and cleaner technologies.

In relation to the above, the main objective of this article is to identify the economic incentives that are being implemented or have been implemented in different countries around the world to promote decarbonization alternatives in the inland waterway and maritime modes. Various sources of information were therefore reviewed, including port websites, related government documentation, interested organizations, and shipping companies. Then, the economic incentives were grouped into categories. This provides an insight into the policies and types of incentives that have been implemented in different regions, which can be used as a basis for research related to the design and implementation of economic incentives in countries that are taking their first steps in decarbonizing the transport sector, such as Colombia.

To fulfill the objective, we aim to answer the following research questions:

- What are the main economic incentives used to promote decarbonization alternatives in maritime and inland waterway transport modes worldwide?
- What economic incentives are being applied to promote decarbonization alternatives in maritime and inland waterway modes?

The article is organized as follows: Section 2 provides the review of the related literature; Section 3 describes the methodological steps for selecting and including information within our review. Section 4 presents the results obtained from the literature review and the discussion of these. Section 5 includes the limitations of this study. Finally, Section 6 presents the main findings of the study and future work.

2. Literature Review

In this section, we reviewed the literature related to the following topics: (a) decarbonization policies, (b) port strategies to reduce emissions, and (c) economic incentives as an environmental measure.

2.1. Decarbonization Policies

In order to achieve deep decarbonization in the waterborne transport sector, it is necessary to implement measures not only from an operational and technological perspective but also from the implementation of national and international regulatory and economic policies that limit the use of polluting fuels and encourage actors to take sustainable actions. In this regard, in [9], the authors reviewed technological and policy options that can be implemented to reduce greenhouse gas emissions from shipping and assessed the feasibility of each option. Regarding decarbonization policies, the authors mentioned that policies should include much stricter targets on efficiency, limiting emissions of sulfur and other pollutants, and speed limits, among others. They also indicated that operational measures must be accompanied by policies, as these can accelerate the effective implementation of low-emission fuels and technologies. The policy options in this study were grouped into three categories: emissions price control approach, which includes taxes, port charges, and rebates; emissions quantity control approach, which includes credits, benchmarking,

and cap-and-trade programs; and finally, the third category is subsidies, which include subsidies and financial assistance to those who implement certain environmental behaviors. Moreover, in [18], the authors reviewed policies at the local, national, and global levels related to air pollution in maritime transport. The authors stated that port and coastal communities are the most affected by local air pollution from shipping transport. Without regulatory and economic policies, these emissions will continue to rise, as the inclusion of zero-emission fuels and technologies tends to be too expensive and unlikely to be implemented without incentives. The policies reviewed by the authors were grouped into three types: market-based policies that include economic incentives, regulatory policies that include national and international governance policies to limit the Sulphur content of fuels, and voluntary policies such as the World Ports Climate Action Program that seeks to support the electrification of ports.

2.2. Port Strategies to Reduce Emissions

The implementation of environmental strategies and policies in ports can reduce environmental impact and have positive effects on the local environment. In [19], the authors discussed the different strategies that ports employ to introduce more sustainable practices and reduce local emissions, pointing out three main methods: onshore power supply (OPS), use of GNL, and slowing ship speeds at the port. The authors also mentioned other methods that have been studied in other research, such as the implementation of technologies that increase the energy efficiency of the port, the application of port tariffs, the generation of own power in the port, and adherence to voluntary discount schemes for green shipping. On the other hand, in [20], the authors analyzed the impact of environmental policies and incentives on ports and how they may affect the port from an economic panorama. Therefore, they performed a dynamic simulation of systems based on the port of Busan, concluding that environmental policies and policy options can bring positive effects and improvements in the port's environmental performance in the medium and long term.

2.3. Economic Incentives as an Environmental Measure

Economic incentives can be a viable strategy for reducing emissions and using green technology in ships and ports. In fact, in [21], the authors studied how economic incentives such as the differentiation of port tariffs can contribute to a green maritime transition and, at the same time, generate social benefits by improving health conditions in the local port environment. The authors worked under a hypothetical scenario where a ship that uses LNG and calls at different ports receives bonuses for reducing its emissions. This study showed that green economic incentives used as market-based measures could reduce emissions levels in ports and ships. In addition, the study found that the higher the bonuses and the more ports around the world use differentiated tariff schemes, the better the results. On the other hand, in [22], the authors conducted a review and classification of initiatives that reduce emissions from maritime transport implemented around the world to establish a global database. Showing that the largest number of incentives have been implemented in European countries. Additionally, the authors highlighted the role of ports, which sold out by adopting stronger policies and economic incentives to address climate change mitigation and adaptation. The study also showed that incentives implemented in the form of discounts at ports provide a strong incentive to adopt low-carbon practices.

3. Methodology

3.1. Selection of Reference Countries

Sixteen countries were selected based on the following criteria: (1) leadership in electricity-powered mobility in their regions, (2) possession of inland waterway networks in their regions, (3) membership in the International Maritime Organization, and (4) official participation in the Paris Agreement and well-established commitments to mitigate and adapt to climate change.

The selected countries were Argentina, Australia, Brazil, Canada, China, Colombia, Germany, Japan, the Netherlands, New Zealand, Nigeria, Norway, South Africa, Sweden, the United Kingdom, and the United States. The selection was based on the availability of information on official and public pages associated with the topic.

3.2. Processes for the Information Gathering

The methodology used for this research has an exploratory, descriptive approach since, firstly, it seeks to review the literature to identify the conceptual framework of the topic addressed and, secondly, because it is intended to classify the data collected into categories in order to analyze them.

For the purpose of obtaining reliable results, the data and information were consulted through online resources provided by the official websites of governments, institutions or organizations involved in the transport sector. The reviewed documents addressed the issues of economic incentives, public policies, differential tariffs, and project financing programs. In addition, reports, articles, and similar study documents that have been produced for this topic were reviewed.

Information obtained from the web portals of government authorities and major inland waterways and maritime ports was also included based on the volume of cargo moved in each of the selected countries. Within this framework, the web portals of 48 ports were reviewed, as specified in Appendix A.

As a criterion for inclusion, only original open-access documents were considered in which economic incentives for maritime modes in the countries analyzed could be identified. This was performed with the intention that other researchers and people interested in the subject could have immediate and free access to the information. Documents in which repeated information was found were excluded from this research, as well as those documents that were not directly related to the topic and those that did not specify any type of economic incentive.

It should be noted that this research did not establish any temporal restriction in order to be able to include the greatest number of economic incentives that promote electric mobility in the maritime and inland waterway modes.

The terms used to search the information on the Internet were: "economic incentives", "electric mobility", "zero emission ships", "green incentives", "maritime transport", "decarbonizing maritime transport", "electric inland waterway transport", "public policies", "policy incentives", "fleet replacement", "port fee differentiation", "greenhouse gas emissions reduction", "green ports", and "alternative fuels". As a search strategy, the keywords mentioned were exchanged and combined in order to include as much information as possible related to the topic.

After applying the above steps, it was possible to find 44 sources as a reference for the different countries addressed. In addition, the scheme shown in Figure 1 was used as a selection algorithm to filter the pertinent information.

At this point, it is important to mention that while performing the information search process through online resources, some aspects, such as the following, were highlighted:

(1) When reviewing the incentive-generating instruments and the sources where promotion decarbonization alternatives in the inland waterway and maritime modes were included, some instruments were found, such as certain regulations and programs, generated more than one economic incentive of different types;
(2) During the included phase, certain instruments were found that aim to support the adoption of decarbonization alternatives in the maritime and inland waterway modality through financing. Some of the instruments found were government plans, strategies, and regulations. However, some of the sources were not considered because they did not specify the requirements to access them;
(3) During the identification phase, it became clear that information compiled on economic incentives to promote schemes to use zero-emission ships and green technologies is not easily accessible. This is because a lot of data are not in the public domain.

Nor were resources found to compile in a general way the situation of incentives by region or to collect updated information on differentiated port charges that are being applied in some of the ports studied. It was necessary manually query each of the web portals of the ports to access the information; however, it should be mentioned that some of these portals did not include it, or this information was not easily accessible; therefore, in order to access it, it was necessary to review the online resources available to the index programs and environmental certifications. It should be noted that the Web Portal of the Department of Energy of the United States has an Alternative Fuels Data Center in which the economic incentives, laws, regulations, and current and non-current programs that promote the use of clean fuels at the federal level and by the state are collected, this information includes the incentives aimed at the different modes of transport. Therefore, it is necessary to carry out filters to identify incentives specifically aimed at inland waterways and maritime modes.

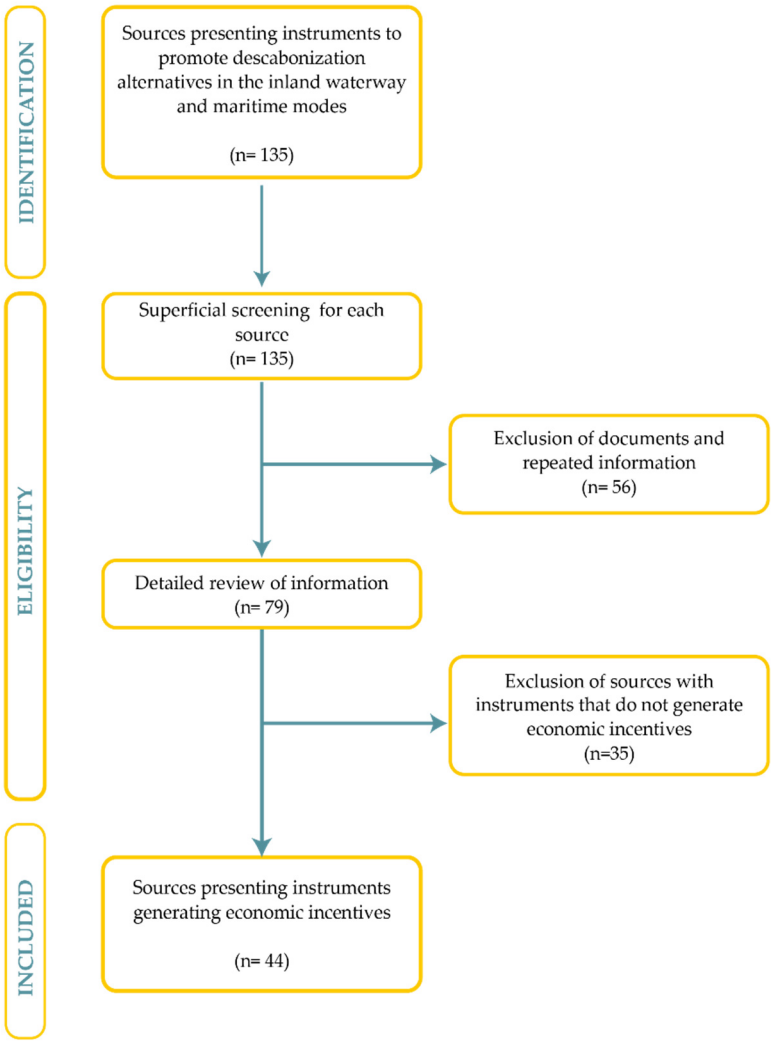

Figure 1. Bibliographic collection diagram.

3.3. Collection and Organization of Information

This phase included the classification of identified incentives and content analysis. The information was organized into characterization matrices (content sheets) by country, in which the following fields were recorded: instruments (public policy, regulation, decree, law, initiative, and programs), a brief description of the instrument, the purpose of change in the face of the decrease in GEIs, economic incentives it generates and source (online resource link). Once the information was organized, incentives were categorized according

to trends or similarities between them. Subsequently, the analysis of the information obtained was performed.

4. Results

This section presents the results of the literature review in order to answer the research questions. Figure 2 shows the number of economic incentives identified, resulting in one hundred incentives.

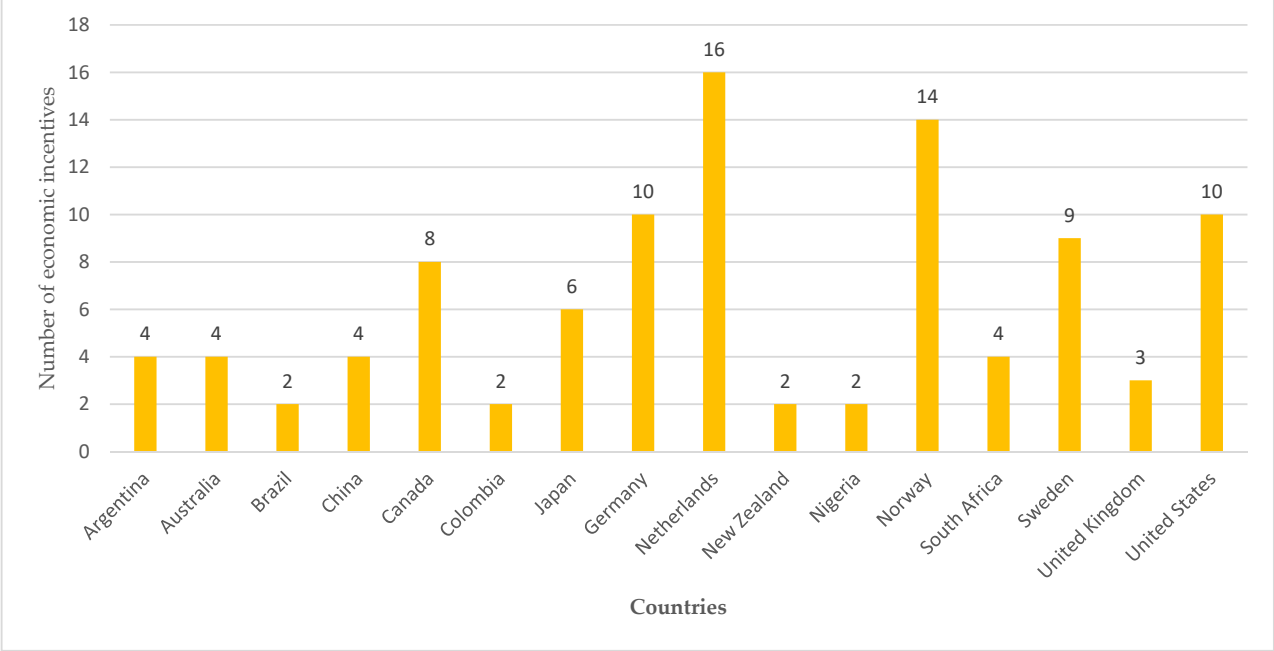

Figure 2. Number of incentives by country.

4.1. Types of Economic Incentives

The one hundred (100) incentives found in the review were classified into the following categories: (1) incentives to cover onshore power service fees, (2) project financing, and (3) differentiated port charges. Each type is described below:

- *Incentives to cover onshore power service fees:* The ships that dock in the ports usually use their auxiliary engines to provide themselves with electricity; this practice contributes to increased local emissions and affects the health of surrounding communities and the environment. The onshore power supply (OPS) is presented as an alternative to reduce local emissions; this technology is described in the IEC/ISO/IEEE standard under the term High Voltage Grounding System. Through this technology, ships can connect to the local electricity grid and turn off their engines while they are docked in the port [23]. OPS provides many environmental and economic benefits to the government, ports, shipping companies, and ship owners, including a reduction in air pollution in ports and local communities and a reduction in GHGs, and, in turn, they allow the port to generate income by selling energy to ships.

Even though OPS has proven to be a technology that can reduce emissions in maritime and inland waterway ports, large investments for the installation and maintenance of OPS technology, the high costs of electricity, and the lack of regulations and incentives hampered implementation both in ports and on ships. Most of the ports that have this technology are located in North America, Europe, and Asia [24]. It must be mentioned that the countries belonging to the European Union are covered by the directive on the deployment of alternative fuels infrastructure 2014/94/EU, which establishes that OPS technology must be installed in the ports of the European Union as a priority before 31 December 2025 [25].

Because of all these factors, some governments have chosen to provide subsidies to ships and ports for the installation of OPS and subsidies to lower electricity tariffs. Table 1 shows the incentives identified in this category.

Table 1. Economic incentives to cover onshore power service fees.

Countries	Economic Incentives	Sources
Sweden	Exemption from payment of electric energy tariff for OPS—Port of Gothenburg	[26]
	Reduced tax measure on electricity supplied to ships by OPS	[27]
China	Subsidy to cover shore power service fees (Inland waterway ports)	[28]

Source: own elaboration based on the literature review.

The results for this category showed incentives in only two countries: Sweden and China. In Sweden, the Port of Gothenburg applies such incentives. For example, ships that connect to shore power supply do not have to pay a tariff for the energy supplied and can obtain high scores in the environmental component to also access differentiated port tariffs [26]. Additionally, Sweden has a measure to apply a reduced tax rate of EUR 0.50/MWh for the supply of electricity to installations supplying electricity to ships at berths in ports with the aim of promoting the use of electricity in ports and reducing emissions [27]. On the other hand, in China, the government has implemented financial subsidies to lower the electricity tariff at OPS [28]. These subsidies are variable and depend on the electricity consumption of ships using the technology at the port.

In the other countries studied, no incentives were found that could be grouped under this category. In that regard, some research determined that reductions and exemptions from electricity taxes can be an effective incentive to promote the implementation of OPS since the price of electricity for OPS tends to be higher compared to the price of traditional fuels [29]. This means that shipowners, shipping companies, and ports are not motivated to implement the technology without economic incentives. By lowering the price of the energy tariff, OPS can become more competitive in the market, as well as contribute to meeting the government's environmental objectives [30]:

- *Projects financing:* international commitments and goals to decarbonize the transport sector are prompting the industry to review other options further than conventional ones that allow for reducing emissions. However, achieving these goals requires the use of alternative fuels, improvements in operational efficiency, and implementation of renewable energies and low-carbon technologies [4,31,32]. These options can include a great challenge for the involved actors: shipowners, shipping companies, and port authorities, given that the financing of infrastructure, the acquisition of new technologies, and the purchase of green ships require greater investments [33]. In this scenario, economic incentives aimed at financing this type of project can play an important role in supporting a sustainable change in maritime and inland waterway transport, covering different scopes such as the development of sustainable port infrastructures, fleet renewal and support on research and innovation [33,34].

By considering the above, the incentives included in this category aimed at financing research, innovation, and development projects of maritime-fluvial technologies or port infrastructure of zero or low emissions. The main sources of funding identified come from governments or private funds and are granted through agencies and programs to projects that seek to improve the environmental performance of ports and maritime or inland waterway ships.

This category also includes grants and subsidies, which are a kind of economic aid or assistance granted by national or local governments, institutions, organizations or individuals for a specific purpose, e.g., the implementation of environmental innovation projects, the implementation of good environmental practices or the acquisition of low-emission technology [35]. These incentives provide financial support to ships with environmental

indices, labels, or certifications; support research and development projects; or support the acquisition of new technologies. Programs that offer grants can be tools that encourage the reduction in emissions in the sector. The Port of Los Angeles in the United States, through its subsidy program, has evidenced a reduction in emissions of polluting gases; however, the port continues to make efforts to encourage green transportation with the aim of complying with the commitments that have been proposed for 2023 [36].

In this regard, the instruments reviewed included grants, programs, and funds aimed at financing maritime and/or inland waterway projects in fourteen of the countries studied, as shown in Table 2.

Table 2. Programs and funds to finance projects by country.

Countries	Grants, Programs, and Funds to Finance Projects	Sources
United State	Port Technological Advancement Program	[37]
	EPA Port Initiative	[38]
	Maritime Environmental and Technical Assistance (META) Program	[39]
	Carbon Reduction Program (CRP)	[40]
	FY21 Office of Vehicle Technologies Research Funding Opportunity Announcement	[41]
	Broad Agency Announcement (BAA)	[41]
	Grants Program—Port of Los Angeles	[36]
	Grants Program—Port of Long Beach	[42]
	Grants Program—Port of New York and New Jersey	[43]
	Port Infrastructure Development Program (PIDP)	[44]
Canada	Salish Sea Marine Emission Reductions Fund	[45]
Norway	Enova	[46]
	NOx Fund	[46]
	EU Horizon 2020	[47]
	TEN-T Program	[48]
	Horizon Europe	[49]
The Netherlands	Incentive Scheme for Climate-Friendly Shipping—Puerto de Rotterdam	[50]
	EU Horizon 2020	[47]
	TEN-T Program	[48]
	Horizon Europe	[49]
Sweden	Grant to invest in vessel conversion for OPS	[51]
	EU Horizon 2020	[47]
	TEN-T Program	[48]
	Horizon Europe	[49]
Germany	EU Horizon 2020	[47]
	TEN-T Program	[48]
	Horizon Europe	[49]
Australia	Australia's Clean Energy Finance Corporation	[52]
China	Financial subsidies for OPS construction—Lianyungang government (inland waterway ports)	[53]
	Financial subsidies for construction and OPS capacity expansion (maritime ports)	[28]
New Zealand	New Zealand Green Investment Finance	[54]
Argentina, Colombia, Nigeria, South Africa United Kingdom	EU Horizon 2020	[47]
	Horizon Europe	[49]

Source: own elaboration based on the literature review.

Results for this category showed the following incentives by country:

- United State: The U.S. government and waterborne transport organizations are aware of the importance of infrastructure development and the implementation of green technologies in the sector, particularly in the context of mitigating GHG emissions and strengthening the U.S. economy. In fact, research addressing freight and passenger transportation has shown that green infrastructure and technologies can be presented as a mechanism to promote economic development not only in the United States but in countries in general [55]. A report by BlueGreen Alliance, together with the Economic Policy Institute, showed that investing in green infrastructure can be an opportunity to address short-term and long-term economic challenges, respectively, enabling job generation and the transition to a low-carbon economy. In shipping and inland waterway transport, green technologies and alternative fuels play an important role in reducing carbon emissions from ships [30,53,56]. This implies that more action must be taken to finance the implementation of infrastructure, technology, and clean fuels.

As shown in Table 2, ten programs were identified that offer financing in the United States, including the Port Technological Advancement Program, which is part of the Clean Air Action Plan adopted by the Ports of Long Beach and Los Angeles and offers funding opportunities for port-related mobile sources projects involving clean or zero-emission technologies for ships and port infrastructure [37]. The EPA Port Initiative is also included, which is a program that supports ports in developing efficient, safe, and sustainable infrastructure, making energy security improvements, and promoting clean transportation, through different resources, including support in finding projects financing and capitalization of financing opportunities that involve clean technologies [38]. At the same time, [39] showed that there is also the federally funded Maritime Environmental and Technical Assistance (META) Program, which provides financial support for projects that improve environmental sustainability in the maritime industry; among the areas covered by the program are emission reduction projects in ports and ships.

In [40], it is illustrated at the federal level; there is the Carbon Reduction Program (CRP), a program authorized by the Bipartisan Infrastructure Act that is currently being implemented. This program aims to reduce emissions in the transportation sector in the states by financing transportation electrification projects and the deployment of vehicles powered by alternative fuels. Among the eligible projects are those that seek to reduce emissions in port facilities. There is also the FY21 Office of Vehicle Technologies Research Funding Opportunity Announcement; this is a program that funds research and proof-of-concept projects related to transportation efficiency and emissions reduction. The lines that can access funding are electrification of transportation, batteries, alternative fuels, vehicle efficiency, and technologies to improve transportation efficiency [41]. On the other hand, the web portal grants.gov announces other programs that offer funding in the United States, such as the Broad Agency Announcement (BAA), which allows funding research and development projects in areas such as energy, mobility vehicles, environmental infrastructures, coastal engineering, etc. [41,57].

In respect of subsidies and grants, the Port of Long Beach, the Port of Los Angeles, and the Port of New York and New Jersey provide rewards to boat operators for reducing emissions and demonstrating the use of low-emission technologies; moreover, ports award grants according to the ESI score of ships [36,42,43]. In addition to this, the U.S. Maritime Administration manages the Port Infrastructure Development Program (PIDP) discretionary grant program, which provides grants to projects related to the transportation of goods by sea, predominantly projects that support efficiency and reliability improvement, and projects that contribute to the mitigation of emissions and the impacts of climate change [44].

- Canada: In this country, during the year 2021, the Salish Sea Marine Emission Reductions Fund was in force, which aimed to support the reduction in emissions from vessels operating in the Salish Sea by providing financing to projects in two ways:

in study projects such as feasibility, technical reviews or research projects on topics such as clean fuels, ship electrification, etc. [45]. In addition, investment projects or installation of technologies for the reduction in emissions in ships. Among the eligible projects, there were lines of change in national fleets or ships to electric technologies and the repowering of cleaner engines, among others [45].

- Norway: In this country, there are financing agencies such as Enova, which belongs to the Ministry of Climate and Environment. Enova allows financing projects in the areas of energy, transport, and GHG reduction. In addition, within the agency, there are special Funds and programs for electrification projects of maritime and inland waterway transport [46,58]. NOx Fund is another financing entity owned by the Norwegian government. This agency supports projects that reduce NOx emissions through the implementation of green technologies on ships, for instance, technologies for shore power supply (OPS) and the installation of charging stations for electric ships in ports [46].
- Netherlands: The Port of Rotterdam introduced the Incentive Scheme for Climate-Friendly Shipping, which allows financing up to 40% of projects related to the implementation of clean fuels for the propulsion of maritime vessels and the reduction in emissions.
- Sweden: The Port of Stockholm offers a subsidy of approximately 95,000 euros for ships that are renewed for onshore power supply and connected to the dock's power grid [51].
- China: the government provides subsidies to finance OPS investment costs. For construction and expansion costs, fixed incentives are generally offered in order to help ports defray the high cost of initial investments for OPS implementation. These subsidies have been implemented in both seaports and inland ports [28,53].

In Australia, the government established The Clean Energy Finance Corporation, a green bank whose purpose is to accelerate investments in research, development, and demonstration of projects that help reduce emissions in Australia from different sources: renewable energy, freight and passenger transport, electrification, fuel switching, among others. New Zealand has New Zealand Green Investment Finance, which is also a green bank established by the government and has the same purpose of supporting the reduction in emissions in the country. Among the cases that have been funded is the Port of Wellington decarbonization project.

Germany, Norway, Sweden, and the Netherlands, countries that are part of the European Union, as well as Argentina, Colombia, Nigeria, South Africa, and the United Kingdom, have had access to programs such as EU Horizon 2020 and Horizon Europe that provide financial support to research and innovation projects focused on low-carbon technologies in maritime and inland waterways modes. Some examples of projects are projects for the electrification of ships and the development of technologies for the supply of energy on land, among others [47–49].

- Differentiated port charges: Differentiated port charges refer to the application of discounted port charges to environmentally friendly ships docking in ports using these unloading schemes. In recent years, more and more ports have chosen to apply this type of incentive on a voluntary basis, making it the most common economic incentive applied to support emission reductions (CO_2, NO_X, So_X, Emissions of Particles (PM)) in seaports worldwide [33]. Ports use discounts as a tool to reduce their environmental impacts while promoting the use of green fuels and the use of low-emission technologies in inland and maritime transport [59].

Many ports choose to adhere to environmental indexes, labels, or certifications in order to apply economic incentives either in port tariffs or other port services. Some ports have their own economic incentive programs that may include ships that have schemes or environmental indices, as well as ships that use an onshore power supply (OPS). The most common application mechanism for this type of incentive is as follows: if the ship

has a certain emission indication score, certification, or environmental label, it will receive, depending on the score, a percentage discount. After the review of port incentives, the schemes listed were: Green Award, Environmental Ship Index (ESI), Clean Shipping Index (CSI), Environmental Port Index (EPI), Green Marine, Right-Ship, and Blue Angels.

From the 45 ports reviewed in this research, which correspond to the main ports of the 16 countries, 25 apply at least one differentiated port tariff scheme. Figure 3 shows the percentage of ports that are and are not applying differentiated port tariffs. We can note that 52% of the ports studied apply this strategy, but 42% do not apply schemes. In order to contribute to the reduction in emissions from the sector, it is necessary for ports to apply incentives such as port fees to encourage shipowners to switch from conventional fuels.

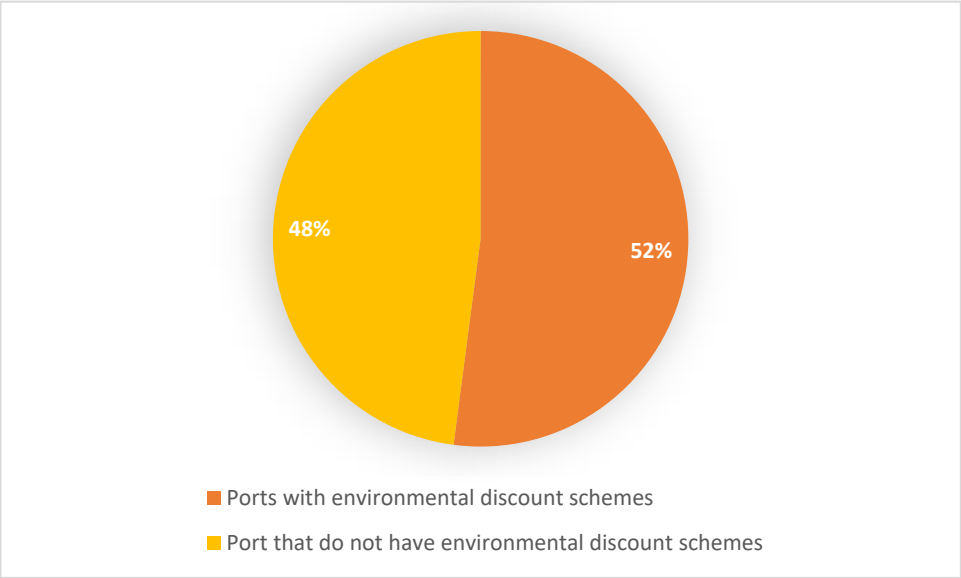

Figure 3. Percentage of ports with schemes and without environmental discount schemes.

In Argentina, the government and the Administración General de Puertos Sociedad Del Estado approved, through Resolution No. 50/2017, the adherence to the environmental programs Green Award and Environmental Ship Index for the Port of Buenos Aires [60]. The regulation determines that ships and cruise ships that have an ESI puncture equal to or greater than 30 will have a 5% discount on port fees. Those with a Green Award certificate or ESI score greater than or equal to 50 will have a 10% discount [60]. Another example of the application of environmental products is the Port of Vancouver, Canada, which through the EcoAction program, offers discounts of up to 47% on port fees depending on the level (gold, silver, bronze) to which the ships are qualified. These are applied to ships adhering to Environmental Ship Index, Rightship, Green Marine, Clean Shipping index, Energy Efficiency Design Index, Green Award, and Clean Cargo Working Group [61]. Ships that use clean fuels or technologies and do not adhere to any of the above programs can receive discounts; the port authority will classify them into one of the tiers according to their level of emissions [61].

It is important to mention that only in the ports of Sweden and the Netherlands have discount schemes been identified for inland waterway ships with Green Award Certificates that use neutral fuels or are propelled by electric energy [50,62–65].

Table 3 shows the number of economic incentives identified for the differentiated port charges category in the ports studied in each country and the respective source of incentive information. Countries whose ports do not apply incentive schemes were not included in the table.

Table 3. Grouping of country-reviewed sources for differentiated port charges.

Countries	Number of Economic Incentives	Sources
Argentina	2	[60]
Australia	3	[66]
Brazil	2	[67]
China	1	[68]
Canada	7	[61,69,70]
Japan	6	[66,71]
Germany	7	[66,71,72]
The Netherlands	12	[50,62–64,66,71,73]
New Zealand	1	[71]
Norway	9	[66,71,74–76]
South Africa	2	[71]
Sweden	3	[65]
United Kingdom	1	[66]

In regards to the above-mentioned, it is important to mention that research related to the implementation of differentiated port tariffs has determined that this strategy can contribute to the reduction in emissions, as well as promote the implementation of green technologies in maritime and inland waterway transport modes [33,77]. In addition, ports can also play an important role in the transition to low-carbon mobility as they can set their own decarbonization strategies, and they can incentivize ships to move towards green technology change [21]. Differentiated port tariffs are voluntary schemes, so ports are not obliged to implement them. Although more and more ports are implementing this strategy, similar schemes need to be adopted in more regions as this could provide an incentive for shipowners to improve the environmental performance of ships.

4.2. Economic Incentives by Country

Table 4 presents a comparative table of the types of incentives that were identified within each country. Economic incentives are grouped into the following categories:

A. Reduction or exemption from payment of electric energy tariff for OPS;
B. Financing projects;
C. Differentiated port charges.

Table 4. Comparison matrix of types of economic incentives identified by country.

Categories/ Country	Argentina	Australia	Brazil	China	Canada	Colombia	Japan	Germany	The Netherlands	New Zealand	Nigeria	Norway	South Africa	Sweden	UK	EEUU
A				x										x		
B	x	x		x	x	x		x	x	x	x	x	x	x	x	x
C	x	x	x	x	x		x	x	x	x		x	x	x	x	

Source: own elaboration based on the literature review.

Furthermore, Figure 4 shows the percentage of incentives by each category of the one hundred economic incentives identified after the review of sources and instruments. The category that includes the most incentives corresponds to that of differentiated port charges (56%), followed by incentives for project financing and subsidies (41%), and the category that includes the least number of incentives identified corresponds to that of reduction or exemption from payment of the electricity tariff (3%).

After reviewing the results, we noted that most of the authors reach the same consensus, although, in some regions, economic incentives are being applied to promote the decarbonization of maritime and inland waterway transport either in the form of discounts on port fees, project financing or reduction in electricity tariffs for OPS; it is necessary that more regions join, more governments apply regulatory and economic policies, and

more ports adhere to or implement incentive programs for ships, since achieving the decarbonization of the sector requires the implementation of actions in conjunction with the entire international community. Bearing in mind that both modes present many challenges that must be addressed to achieve low-emission mobility, inland waterway transport, for example, lags in many regions; its main challenges include the installation of resilient and low-carbon port infrastructure, installation of inland terminals to improve the quality of river connections, and implementation of alternative fuels for ships and barges. For its part, maritime transport needs to take stronger action to replace marine-conventional fuels with lower-carbon fuels, electrify fleets, and implement OPS in more ports. All these challenges can be solved by means of economic policies and technological and operational measures. Without stronger regulatory and economic policies, emissions levels in both modes are likely to continue to rise.

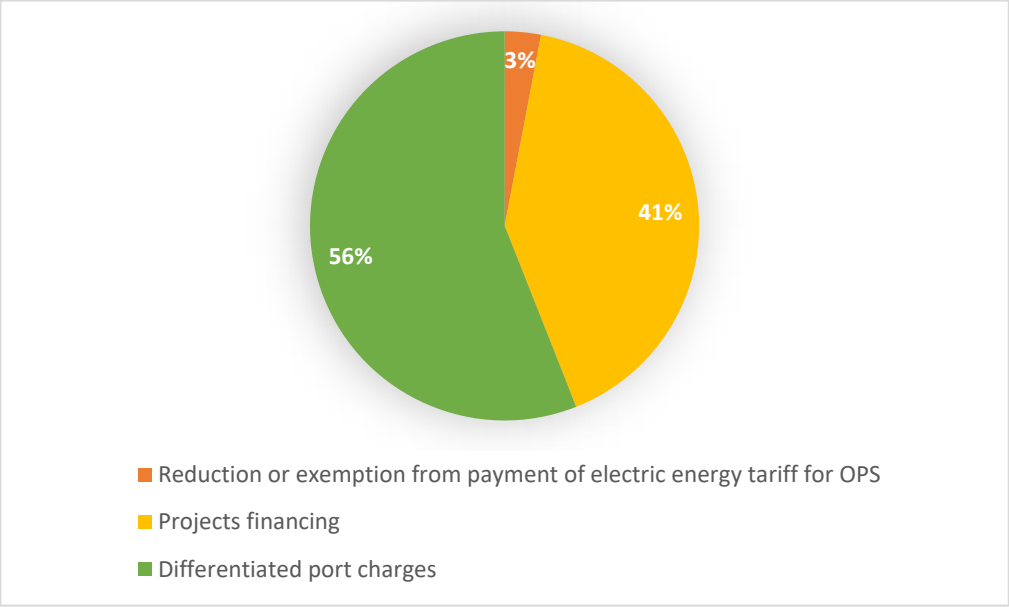

Figure 4. Percentage of incentives by type.

4.3. Colombian Case

Colombia is a country rich in water resources, with more than 1400 km of rivers running throughout the country. In addition, the country has access to the Pacific Ocean and the Caribbean Sea. In the maritime mode, Colombia has nine port zones, and most of the merchandise exports are carried out by the sea. As for the inland waterway mode, although it is a very efficient means of transporting large quantities of goods. This mode is also the main means of passenger transportation for many communities living in remote areas of the country. However, the maritime and inland waterways modes in Colombia present many challenges and great needs for infrastructure development and modernization, not only to improve their efficiency and competitiveness but also to cope with climate change [78]. In order to comply with environmental commitments, measures are being taken in the country to decarbonize the transport sector.

In that regard, Colombia has undertaken to ensure environmental integrity and to take action to counteract the effects of climate change by becoming a party to the United Nations Framework Convention on Climate Change (UNFCCC). It also showed its commitment through the approval of the National Climate Change Policy in 2017, and the Climate Change Law approved in 2018. At the same time, the country has public policy tools related to climate change, including the National Climate Change Policy, the National Electric Mobility Strategy, the National Plan for Adaptation to Climate Change, and the National Development Plan 2018–2022: Pact for Colombia, Pact for Equity.

As actions, in recent years, strategies have begun to be designed and implemented to accelerate the penetration of electric mobility. However, Colombia's transition to low-emission mobility lags far behind other countries that have already employed stronger policies. Colombia must continue to focus on the development of strategies and comprehensive solutions that promote sustainable development and reduce the carbon footprint. However, these measures should not only focus on the roadway transport sector, where there is already more progress in terms of tax incentives and environmental policies but also on the maritime and inland waterways sector, where urgent action is needed.

Regarding the ports, the main ports of Colombia are located in Barranquilla, Cartagena, Santa Marta, and Buenaventura. Their official portals did not identify economic incentives or differentiated rates of port fees for sustainable ships. However, it should be noted that the ports mentioned here have environmental management plans.

The Port of Barranquilla has an air quality and infrastructure monitoring plan to verify that the permitted limits are not exceeded. This is performed through the inspection, monitoring, and maintenance of vehicles and the port infrastructure [79].

In addition, the Sociedad Portuaria de Buenaventura has a program for the management of operations likely to generate atmospheric pollution during adaptation, construction, and operation, which seeks to prevent global atmospheric damage during the execution of works and operation of port facilities [80].

The Port of Cartagena and the Port of Santa Marta carry out activities to minimize the emissions of articulated material. The port of Cartagena, for example, opts to acquire state-of-the-art equipment and technologies that require lower fuel consumption to achieve cleaner combustion. The port also has an electrification program for cranes RT, which aims to replace cranes that use diesel in their operation and use electric cranes [81,82].

Given that Colombia is just taking the first steps towards the implementation of economic incentives to promote decarbonization alternatives in the maritime and inland waterway mode, the implementation of initiatives and incentives that other countries are implementing is a possible way forward. These incentives may be applicable to specific regions of the country or to the country as a whole, considering the orientation and objectives that Colombia has set itself in terms of reducing greenhouse gases. Among the aspects to be prioritized in these incentives is the development of infrastructure, modernization of passenger transport fleets, restoration of docks, and science and technology projects. Building on some of the incentives that are in place or that have been implemented in other countries can be an advantage in designing incentives that can bring economic, environmental, and social benefits.

According to international experience, Colombia may consider the following:

(1) Establish programs that are especially aimed at financing implementation projects such as the modernization of ships and improvement of port infrastructure;
(2) Establish agreements with financial institutions so that ports, shipping companies, and ship owners can access loans with differentiated interest rates for the development of low-emission infrastructure or for the deployment of green technologies on ships;
(3) Establish programs that support development and innovation research for electric transportation in the inland waterway and maritime modes;
(4) Establish alliances between government, business, and academia to finance and carry out research to improve the efficiency of battery capacity and existing technologies related to electric mobility in the maritime and inland waterway sector;
(5) The voluntary introduction of differentiated port tariffs in ports encourages the use of low-emission technologies and green ships;
(6) Adherence to environmental programs, indices, labels, and certifications to provide incentives for green ships;
(7) Establish grant programs to support research, feasibility studies, demonstration projects, etc.;
(8) Provide subsidies and financial assistance for the purchase and installation of technologies to reduce emissions on ships and in ports;

(9) Consider, at this point, economic incentives such as grants, subsidies, discounts, or others to promote the installation of shore-side power supply systems in ports;
(10) Establish government strategies and policies that generate economic incentives to enable the deployment of OPS systems and the installation of charging stations for maritime and inland waterways ships.

5. Limitations of This Study

Data in this article were taken from academic and documentary sources, databases such as Google Scholar, Scopus, and websites of institutions related to the waterborne transport sector were reviewed. This approach limits the study as there may be more sources related to the subject that can contribute to the results and provide a broader picture of economic instruments in each country. In addition, it should be mentioned that the economic incentives identified are limited only to the countries studied here; it is possible that other countries are implementing different types of instruments that generate economic incentives aimed at promoting different decarbonization alternatives.

On the other hand, some data from inland waterway ports and maritime ports, as well as access to legal and policy information in some Governments, are restricted and not easily accessible, limiting the development of further analysis of the research.

It should also be mentioned that the keywords used to search the information limit our research since it is possible that with other combinations or more keywords included, relevant sources can be retrieved.

Finally, the categories for the classification of incentives were carried out at the personal criteria of the authors according to the tendencies and similarities of the instruments and incentives identified. Other studies may classify or group incentives according to different thematic criteria, so analysis and interpretation of the information may lead to a change in the results.

6. Conclusions and Future Works

This paper presented the results of the literature review related to economic incentives that promote decarbonization alternatives in maritime and inland waterway modes. Through this review, it was possible to identify what economic incentives are being implemented in different countries and what types of incentives can be found for such a purpose. Therefore, we established two research questions: What are the main economic incentives used to promote decarbonization alternatives in maritime and inland waterway transport modes worldwide? What economic incentives are being applied to promote decarbonization alternatives in maritime and inland waterway modes? In order to answer the questions, we reviewed different online resources provided by official portals of governments, institutions related to the transport sector, shipping companies, ports, environmental labels, and certifications of the maritime and inland waterway industry. Filtering criteria were applied to select only the sources that contained information relevant to the study. From this process, we obtained 44 sources with relevant information.

After reviewing the selected sources, it was possible to group the incentives identified into three categories: differentiated port tariffs, project financing, and reduction or exemption of electricity tariffs for OPS. It was found that differentiated port tariffs were the most common type of incentive. The causes of this include the growing environmental pressures of which the ports must take advantage to support the commitments of adaptation and mitigation to climate change. In addition, there are a variety of indexes, labels, and certifications that allow interested ports and institutions to know the emission levels of ships docking at their docks, making it easier to implement this strategy compared to others. On the other hand, the category where fewer incentives were identified corresponds to incentives to cover onshore power service fees. The reason why this incentive is not so common is that this technology is only available in a few ports, mostly in North America, Europe, and Asia. Shore-side power supply systems have not been implemented in many ports due to the economic challenges they face in deploying shore-side power solutions, as

large investments involving implementation and operating costs are required in both the port and the ships connecting to the system.

The literature review also enabled us to determine that governments and ports can help accelerate the decarbonization of the sector through economic policies, regulations, and the implementation of stricter measures to support the transition to zero-emission activities. On the one hand, governments can design and implement incentives such as funding programs and subsidies to support research, development, and deployment of clean fuels and technologies. The government's benefit from this is linked to social welfare and the fulfillment of environmental commitments. On the other hand, the implementation of decarbonization alternatives in ports can improve port competitiveness and environmental management. If such measures are adopted in more countries and ports, the transition to low-carbon mobility in maritime and inland waterway modes can be accelerated, bringing social and environmental benefits.

We can also highlight the role of economic incentives in promoting fuel transition. When incentives are applied to the price of alternative fuels and the electricity tariff, the price of alternative fuels decreases, and their competitiveness against conventional fuels increases, which motivates shipowners to make investments to modernize their ships. Additionally, port tariffs would play a key role in this regard by promoting and providing access to clean fuels at their facility. Other incentives, such as access to financing, may be possible if governments, private companies, and banks generate partnerships that benefit projects in these sectors, which would make it possible for funds and lines of financing to emerging, especially for sustainable development and renewable energy projects.

Finally, as future work, additional studies can be carried out that include other countries in order to have a more global perspective of economic incentives and to identify which economic instruments are being applied in those regions. This is important because conducting studies to identify how incentives are being addressed and how they influence the adoption of cleaner means of transport is an opportunity for developing countries to build on these practices and design their own economic instruments to promote decarbonization alternatives.

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Appendix A

Table A1. List of Ports Reviewed.

Number	Country	Port
1	Argentina	Port of Buenos Aires
2	Argentina	Zarate Port
3	Argentina	San Pedro Port
4	Australia	Port Hedland
5	Australia	Port of Adelaide
6	Australia	Port of Brisbane
7	Brazil	Santos Port
8	Brazil	Port of Pecem
9	Brazil	Port of Santarem
10	Canada	Port of Vancouver
11	Canada	Port of Montréal
12	Canada	Port of Prince Rupert
13	China	Port of Shanghai
14	China	Port of Shenzhen
15	China	Port of Ningbo-Zhoushan
16	Colombia	Port Society of Buenaventura
17	Colombia	Port of Cartagena
18	Colombia	Port of Barranquilla
19	Germany	Port of Hamburg
20	Germany	Ports of Bremerhaven and Bremen
21	Germany	Jade Weser Port
22	Japan	Port of Tokyo
23	Japan	Port of Nagoya
24	Japan	Port of Yokahoma
25	The Netherlands	Port of Rotterdam
26	The Netherlands	Port of Amsterdam
27	The Netherlands	Port of Moerdijk
28	New Zealand	Port of Tauranga
29	New Zealand	Port of Auckland
30	New Zealand	Port of Wellington
31	Nigeria	Port of Lagos
32	Nigeria	Port of Tin Can Island
33	Nigeria	Calabar Port
34	Norway	Port of Oslo
35	Norway	Port of Stavanger
36	Norway	Port of Bergen
37	South Africa	The Port of Durban
38	South Africa	Port of Richards Bay
39	South Africa	Port Elizabeth
40	Sweden	Port of Gothenburg
41	Sweden	Port of Trelleborg
42	Sweden	Ports of Stockholm
43	United Kingdom	Port of Immingham
44	United Kingdom	Port of Felixstowe
45	United Kingdom	Port of London
46	United States	Port of Los Angeles
47	United States	Port of Long Beach
48	United States	Port of New York and New Jersey

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